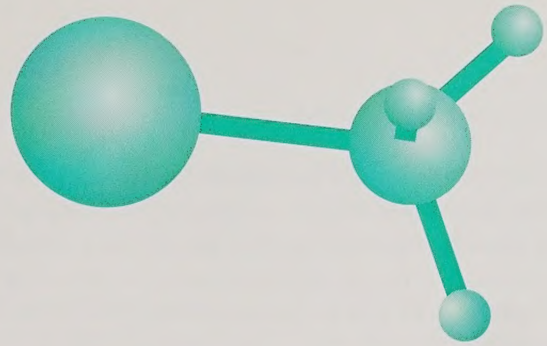
Methyl Bromide *Alternatives*



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Inside This Issue

This issue and all back issues of the *Methyl Bromide Alternatives* newsletter are now available on the Internet at **<http://www.ars.usda.gov/is/np/mba/mebrhp.htm>**.
Visit the ARS methyl bromide research homepage at **<http:/www.ars.usda.gov/ismbmebrweb.htm>**.

This newsletter provides information on research for methyl bromide alternatives from USDA, universities, and industry.

Address technical questions to Kenneth W. Vick, USDA, ARS, National Program Staff, 5601 Sunnyside Ave., Beltsville, MD 20705–5139. Phone (301) 504–5321, fax (301) 504–5987.

Address suggestions and requests to be added to the mailing list to Sharon Durham, USDA, ARS, Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705–5129. Phone (301) 504–1611, fax (301) 504–1641, e-mail sdurham@asrr.arsusda.gov

From the Deputy Secretary

This issue marks the fourth anniversary of the United States Department of Agriculture (USDA) *Methyl Bromide Alternatives* Newsletter. In our first issue, I explained that our intention was to use this newsletter as a vehicle to keep you abreast of the developments in the methyl bromide alternatives research area and to serve as a link between researchers and agricultural producers, marketers, and consumers. I hope we are fulfilling our purpose and that you have found the newsletter useful. In this anniversary issue I would like to address some current methyl bromide issues and activities.

The search for methyl bromide alternatives remains a high priority concern for the USDA and the administration. There is an ongoing, intensive research effort by Federal, state, university, and private industry experts to develop practical, effective, economical, and environmentally acceptable methyl bromide alternatives for growers and other methyl bromide users. Alternatives have been found for some important methyl bromide uses, but much remains to be done.

This was brought home to me during a recent meeting I had with California cut-flower growers to discuss the methyl bromide issue. These growers produce several hundred different crops (with a farm gate value of $360 million) in a climate of intensive competition from abroad and shrinking profit margins. The great number of crops involved, the relatively small acreage associated with each, and the reluctance of pesticide companies to register pesticides for use on cut flowers because of product liability issues have resulted in few registered, practical, and effective methyl bromide replacements for this industry. In other industries, the problems involving the loss of methyl bromide might vary, but the consequence is the same—no available alternative to methyl bromide.

Back in 1993, I recognized that USDA's research and the Environmental Protection Agency's (EPA) registration programs would have to be closely coordinated if acceptable methyl bromide alternatives were going to be found. EPA Administrator Carol M. Browner and I established the USDA/EPA Methyl Bromide Working Group to accomplish this goal. That group has been especially busy this year working to inventory and resolve regulatory issues that prevent currently registered chemicals from being used to replace methyl bromide. The status of that activity is presented elsewhere in this issue.

In addition to research, which is vital, there are several other steps involved with bringing a methyl bromide alternative to the marketplace.

First, a registrant must come forward to assemble the toxicological and environmental safety package to be reviewed by the EPA, a process which costs many millions of dollars. If registration is successfully accomplished, the registrant must manufacture and market the product in sufficient quantity to satisfy market needs. Finally, and perhaps most importantly, growers and other users must accept and use the product. If any one of these steps is missing, then alternatives will not be forthcoming. USDA and EPA are working closely with registrants to expedite this overall process.

An important development to note is the modification of the U.S. Clean Air Act, which the President signed into law last year. It extends the complete phaseout of methyl bromide until 2005 for the United States so as to make the schedule the same as for other developed countries. It also includes important quarantine and preshipment exclusions, as well as provisions for critical use and emergency exemptions where viable alternatives have not been found for methyl bromide uses. Also, for FY 2000, the administration has proposed a new grants program supporting commodity-specific methyl bromide transition projects. These funds will be competitive and will be available to growers and other eligible stakeholders for field trials and demonstration projects. The Senate has approved this new program and I am hopeful that the House and Senate conferees will continue to support this important initiative as the budget process draws to a close for the year.

With best wishes,

Rich Rominger

Richard Rominger
Deputy Secretary
United States Department of Agriculture

USDA/EPA Working Group Update

The USDA/EPA Methyl Bromide Working Group was organized in 1993 to coordinate development and registration of methyl bromide alternatives. For the last several months, this working group has been studying the registration status of potential alternatives with the goal of working with registrants to adjust registrations to maximize their usefulness as methyl bromide alternatives.

First, the working group is working with growers and researchers to discover and evaluate the most promising alternatives, and meetings have been held to discuss critical issues and potential alternatives for strawberries, tomatoes, peppers, other fruits and vegetables, sod, nursery, floriculture, and postharvest uses. These discussions will form the basis for future work on methyl bromide alternatives.

Second, the working group is identifying data requirements, associated costs, and likely registration issues for new active ingredients that scientists have identified as potential methyl bromide alternatives; for example, methyl iodide and propargyl bromide.

The working group is talking with registrants to identify and encourage industry registration activity related to methyl bromide alternatives. DOW Agrosciences briefed EPA and USDA in late July on its strategy and research on alternatives. A follow-up meeting to coordinate research priorities between ARS researchers and DOW was held in Fresno, California, in August.

EPA's Office of Pesticide Programs has implemented a policy that gives expedited registration review to all applications of alternatives. Given that there currently exists a 4-year backlog of registration applications, expedited review status can significantly shorten the amount of time it takes to get a registration decision. Three methyl bromide alternatives are currently undergoing active registration review and assessment: Ecofume, dazomet, and vorlex.

In addition, the Office of Pesticide Programs is reviewing reregistration issues associated with some of the more promising older chemicals such as phosphine, telone, and pebulate (Tillam) to address issues and data needs that would allow these pesticides to help replace methyl bromide uses.

Despite significant progress by the working group, there remain serious obstacles to be confronted. Many older chemicals that could potentially be expanded to cover some methyl bromide uses currently have label restrictions due to concerns about potential worker and bystander exposure, potential groundwater contamination, and potential ambient air-quality degradation. Additional data will likely be needed to rebut these concerns or demonstrate that new formulations and application methods in development can mitigate them.

Economic considerations also pose a significant obstacle. When determining what portfolio of potential new active ingredients to invest in, companies seriously weigh many factors including the net present value of future estimated income streams for each pesticide candidate, payback times, registration and production costs, potential crop damage liabilities, and other uncertainties. At present, methyl bromide alternatives do not seem to compare favorably with other more commercially viable options.

With these considerations in mind, the interagency working group is attempting to address growers' needs by working with registrants to expand, where possible, the uses of existing pesticides to cover some methyl bromide uses. The addition of new uses for older chemicals will likely take several years to accomplish where it is possible at all.

At the same time, the working group is assessing the potential for registration of new pesticides such as methyl iodide and propargyl bromide. Developing the data necessary to register a new active ingredient typically takes 4 years, plus, under the best of circumstances, one additional year for EPA to review the data, perform the appropriate risk assessments, and make a registration decision.

Given the very short time period for the mandatory phaseout of methyl bromide—a second 25-percent reduction in use by 2001 with complete phaseout by 2005—USDA's, EPA's, and the industry's best joint efforts will be required to bring alternatives to the marketplace in a timely manner in order to minimize the disruption to agriculture.

Use of Methyl Bromide for Quarantine and Preshipment

The environmental benefits of reducing methyl bromide use are being eroded by its increasing use for quarantine and preshipment," says Tom Batchelor, cochair of the United Nations Environment Programme, Methyl Bromide Technical Options Committee (MBTOC).

MBTOC was established in 1992 by the Parties to the Montreal Protocol on Substances That Deplete the Ozone Layer to identify existing and potential methyl bromide alternatives. There are 39 members of MBTOC—13 from developing countries and 26 from developed countries.

MBTOC members met in 1998 to undertake another detailed assessment of the uses of methyl bromide and its alternatives (available on www.TEAP.org). In their report, MBTOC found that quarantine and preshipment (QPS) uses once thought of as minor have become major.

In the international schedule to phase out methyl bromide, governments under the Montreal Protocol agreed that developed countries would cut methyl bromide consumption by 25 percent in 1999, 50 percent in 2001, 70 percent in 2003, and phase out by 2005. QPS and critical emergency uses are exempt from these controls. Developing countries need to reduce their consumption by 20 percent in 2005 and to phase out in 2015, except for QPS and critical emergency uses. Countries are encouraged to cut consumption faster than the schedules, where possible.

"Initially, since most of the methyl bromide used worldwide was not on QPS commodities, there wasn't a great emphasis to regulate it," says Batchelor. "But surprisingly, we found QPS consumption has increased to about 22 percent of global fumigant use for both developed and developing countries." This is primarily due to the fact that import and export trade throughout the world has been increasing. Methyl bromide is one of the main quarantine treatments for rapid treatment of imports—fresh fruits, vegetables, flowers, timber, grains—found on arrival to be infested with unwanted pests.

For more than 40 years, methyl bromide has been widely used as a

fumigant to rid soil, structures, and commodities of damaging pests. It has been an effective and economical product. The problem is no single replacement can do the job of methyl bromide.

Many countries have not considered replacements for disinfesting agricultural and horticultural products prior to export or on arrival, and the blanket exemption acts as a disincentive to funding research on QPS alternatives. There are, however, non-methyl-bromide QPS treatments that could become more widely used in the future depending on the pest, commodity, and situation, according to Batchelor.

Some examples of QPS treatments for perishable commodities include cold, heat, irradiation, air or water treatments to dislodge pests, other pesticides or fumigants, and combinations of some of these treatments. Durable commodities have a wider range of alternatives than perishables because they are generally able to tolerate more extreme conditions. Examples of treatments for durable commodities and structures include controlled atmospheres, increased use of integrated pest management, steam, freezing, and combinations of these approaches.

"If we project our minds into the future and think of a time when all uses of methyl bromide, including for QPS, will be banned, critical-use exemptions would continue to allow the use of methyl bromide for QPS in cases where alternatives are not available. In this way, countries could still continue to have quarantine security and minimize the risk of exotic pests being transported across international and state borders," says Batchelor. "In the meantime, having a blanket exemption for quarantine is not in the best interests of the ozone layer," he says.

Batchelor says the Australian agricultural industry has been funding alternatives for soil treatments via a levy on imports for a number of years. He adds, the industry is now considering extending this to include developing alternatives for QPS, since it recognizes the QPS exemption may not last forever. Australian growers, however, do not want to be the last country in the world using methyl bromide, as they predict it will be more expensive in the future and there could be trade sanctions against its use.

MBTOC calculated that, globally, 18 percent of methyl bromide was used for QPS in 1992. This is estimated to have reached 15,000 tons or 22 percent of global consumption in 1996, according to the latest figures available. QPS uses are still increasing sharply in some countries.

"MBTOC also identified countries where QPS uses have been eliminated or reduced. For example, Denmark eliminated QPS uses in 1998, relying instead on alternatives and, if necessary, special exemptions under ministerial approval, and The Netherlands has substantially reduced QPS uses," says Batchelor.

At the 10th meeting of the Parties in Egypt in November 1998, government representatives registered their concern at the increasing methyl bromide use for QPS and requested that MBTOC produce a report addressing their concerns. The report highlighted the additional consumption of methyl bromide, provided options to the Parties for clarifying the definitions of QPS and offered guidance to the Parties on how to accurately report on QPS consumption. Batchelor says MBTOC noted that "there may be some inconsistency in the interpretation of the terms 'quarantine' and 'preshipment,'" which might have resulted in multiple applications of methyl bromide when a single application just before shipment would satisfy the sanitary or phytosanitary requirements of the importing or exporting country.

To assist in this area, MBTOC produced a logic diagram so government regulators can make up their own forms for accurately monitoring, reporting, and differentiating QPS consumption (exempt control) from non-QPS consumption (controlled and reducing in volume). Based on their concern about QPS consumption, one of the options facing government representatives is to put in place compulsory reporting systems and possibly make them retrospective for several years, making it easier to see trends in consumption over time. The Parties may decide in Beijing in November/December 1999 if any further controls for methyl bromide are appropriate.

Treating products before shipment when there may be more time is generally better than treating them on arrival, since even minimal delays in reaching the market destination are important. "I think there will be more effort put into isolating the cause of problems through quality assurance procedures that aim to minimize pest contamination in all parts of the chain," says Batchelor. "There may also be more pressure put on regulators in the importing country to consider a wider range of alternatives than they have had to

consider in the past. The onus, however, will be on technical experts in the exporting country to demonstrate the quarantine security of whatever alternatives are developed," he says.

Forced Hot-Air Treatments Moving Forward for Citrus

Naval oranges have recently been added by USDA's Animal and Plant Health Inspection Service (APHIS) to the list of citrus from Mexico and areas of the United States infested with fruit fly pests that can be treated with high-temperature forced air as an alternative to methyl bromide fumigation. The forced hot-air treatment was approved for grapefruit, tangerines, and oranges other than naval oranges in December 1998.

The approved treatment calls for the temperature at the center of largest fruit to be raised to 44° C (111° F). If it takes less than 90 minutes for the fruit center to reach the target temperature, the fruit must remain at that temperature for whatever additional time is needed to reach the 90-minute mark plus another 100 minutes. The heating is monitored by temperature probes placed inside the largest fruit at the coolest part of the treatment chamber.

Cooling time after the treatment is irrelevant because the amount of time at the increased temperature ensures the killing of any fruit fly larvae, so APHIS is not requiring any specific cooling period. A cold water spray may be used to speed cooling.

Mexico is a major supplier of citrus to the United States, providing one-third or more of all the oranges imported. In 1998, Mexico exported 9,100 metric tons of oranges and 3,100 metric tons of tangerines to the United States.

AMECAC, a cooperative of Mexican growers, is close to having the first forced hot-air chamber for citrus ready for APHIS certification. The chamber is located in Montemorrelos, Mexico, and is expected to have the capacity to treat eight tons of citrus at a time. The Mexico Citrus Exporters Association estimates that use of the new facility once certified could lead to the export of an additional one million pounds of oranges to the United States a year. One million pounds was about 5 percent of the total Mexican orange imports into the United States in 1998.

In the regulated parts of Texas, more than 19 million pounds of citrus were treated with methyl bromide in 1997, with about 90 percent of it shipped to California. APHIS expects that Texas citrus producers will be closely monitoring Mexican experiences with the new treatment.

Forced hot air has been approved as an option for quarantine treatment. Methyl bromide for quarantine use continues to be exempt from the coming ban. But the fumigant does cause some loss of quality in citrus, sometimes causing bronzing—which damages the appearance of the fruit. In addition, as the supply of methyl bromide produced each year drops in response to phased-in reductions, the cost of methyl bromide is likely to increase.

The forced hot-air system not only provides as effective a treatment as methyl bromide against Mexican and Mediterranean fruit flies, but it is less phytotoxic and less damaging to fruit quality. A side benefit of the forced hot air is that it also kills the fungi that create green mold, one of the major pathogens that diminishes the shelf life of citrus.

The concept of using forced hot air for quarantine treatment is not brand new. The treatment has been used for several years to kill fruit flies on papaya being shipped from Hawaii. What is novel about forced hot air for citrus is that it specifies a fruit-center temperature profile so that it can be used for multiple commodities. Both the papaya and citrus treatments are the result of work by USDA's Agricultural Research Service.

Entomologist Robert L. Mangan and plant physiologist Krista Shellie with the ARS Crop Quality and Fruit Insects Research Unit in Weslaco, Texas, developed the treatments that APHIS approved for citrus. Shellie and ARS entomologist Donald B. Thomas have continued to explore the possibilities of forced hot air.

In a recent study, Shellie and Thomas found that the rate at which the fruit is heated affects the time it takes to reach "probit 9," the point at which 99.9986 percent of insects have been eliminated. "Using a very fast ramp up to the target temperature, you get probit 9 at 95 minutes after the fruit center reaches 44° C, versus 104 minutes to reach probit 9 with a slower ramp," Shellie says. "In other words, if you heat it fast, you don't have to heat it as long to get your effect."

APHIS requirements are designed to ensure that no matter what speed of temperature increase is used, treated fruit spend sufficient time at 44° C to ensure a lethal dose to insect larvae. "But our results show that it is important to consider the link between approach time and holding time," Shellie adds.

Thomas also found that, when a slow ramp was used, a high percentage of the fruit fly larvae produced heat-shock proteins. These proteins, which insects produce in response to stress, can help protect the insects from future exposure to stress. When heating to 44° C took 120 minutes, 76 percent of the insect larvae tested had detectable levels of heat-stress proteins. With a ramp of 20 minutes, only 42 percent of the larvae showed heat-stress proteins. "With the fast rate, the insects die before they have time to produce the protective protein," Thomas says.

Understanding the biology of how insects react to forced hot air will allow the development of more refined treatments and APHIS requirements, he adds.

Research for Methyl Bromide Alternatives May Benefit Organic Growers

The Agricultural Research Service's methyl bromide alternative research program is investigating a wide range of approaches to replace methyl bromide. Many of these may fit well with organic farming practices. Because of that, organic growers could reap benefits even though the research may not be specifically directed toward helping them.

Even though efforts to research chemical alternatives still continue, ARS and other institutions are also focusing research on finding cultural and biological alternatives that organic farmers can put to use. For example, Dan Chellemi with ARS' U.S. Horticultural Research Laboratory in Fort Pierce, Florida, is working on soil solarization systems that could be incorporated into conventional or organic vegetable production systems to help control nematodes and weeds. While soil solarization has long been used by organic growers, Chellemi has developed ways to improve the technique by incorporating organic amendments to create an effective nonchemical alternative to methyl bromide.

Working with Vero Beach, Florida, organic grower Kevin O'Dare, Chellemi has been testing a combination of manures and recycled yard materials added to the beds. The beds are then wet down before they are covered with clear plastic to start the solarizing. "The organic amendments encourage the buildup of beneficial microbes," Chellemi says. "And as this compost-soil mixture heats up, it produces gases—primarily methane—that displace soil oxygen. As a result, weeds are unable to germinate." The organic amendments could also be used alone, but Chellemi believes some sort of combination will be the most effective control.

O'Dare claims that using Chellemi's system of organic amendments and solarization has saved his business. "I can't say enough for it," O'Dare says. Purple nutsedge was close to taking over the ten acres of his Osceola Organic Farm, and would have been difficult to control even with chemicals. By O'Dare's second year of solarization, production was up 30 percent, labor was down 75 percent, and profits were up 100 percent. O'Dare's ten varieties of lettuce, tomatoes, peppers, squash, eggplant, and culinary herbs require less water and fertilizer with Chellemi's system. "It's a very sustainable system," O'Dare says.

Jim Stapleton, an integrated pest management plant pathologist with the University of California, has also been looking at combining soil amendments and solarization as an alternative to methyl bromide for vegetables, ornamentals, and strawberries. His approach is essentially the same as Chellemi's, but he is developing the biologically based technique to work in an arid, desert environment instead of a humid, subtropical climate.

"The trick we need to figure out to make the system work for conventional farmers is how to tailor soil amendments to specific crops," Stapleton says. He is experimenting with a variety of crop rotations and amendments that best suit his climate and the economics of the region.

Many large farmers in California are committed to an intensive production schedule, growing two or three crops a year on the same land. Some crop sequences are more likely to result in fewer soil pests. "The residue of one crop can keep down the pests of the next crop if you use the right sequence," Stapleton explains.

Organic farmers have been quicker to adopt the solarization and soil

amendments techniques. "It has been really easy working with organic growers to test the new systems—they pick it up and run with it," Stapleton says. "It is harder for corporate farms to convert to knowledge-based systems like solarization and tailored amendments because the work on such large farms is more partitioned—with a separate irrigation person and a pest manager and all the rest. Everyone has to accept the new idea and decide to apply it. The small organic farmers make all or most of their own decisions. If they buy into a new strategy, they can institute changes almost immediately," he says.

And methyl bromide has worked so well for so many years, there has been no impetus for non-organic growers to look for alternatives. "Now, with the ban coming, other farmers are more willing to look at techniques that organic farmers have been quicker to adopt because they had to have something besides chemicals," Stapleton adds.

Stapleton is also working on the problem of producing clean nursery stock for farm planting without the use of methyl bromide. The California Department of Food and Agriculture recently accepted a protocol he developed using solarization to kill nematode and fungal pests in soil and containers that are then used to raise clean nursery stock. Solarization can be used to bring the soil to a temperature of 70° C (158° F) for at least 30 minutes, under the new regulation. Stapleton is currently looking at the effectiveness of lower temperatures, such as 60° or 65° C, for longer periods of time.

Soil solarization is not optimal for strawberry nurseries in California because many of them are in northern California at high elevations, where it is too cool to depend on the sun for solarization, Stapleton points out. He is looking at the potential for using artificial heat sources to produce clean nursery stock. "But a containerized system is going to be easier to disinfect than trying to do it in a field situation," Stapleton says.

Jim Cochran, an organic strawberry grower in Santa Cruz, California, has been using organic farming methods for 15 years. He uses crop rotation systems with crops such as broccoli and cauliflower, along with soil amendments. "I hope researchers can find effective methods that can be used by organic farmers," he says. "But I don't expect any magic results within the next couple of years. Organic farming is a complex system that requires a long-term commitment."

Cochran also agrees with Stapleton's point that, in some cases, farmers have been moving much faster than researchers when it comes to biological alternatives to methyl bromide. "Many major growers in our region have moved large blocks of prime farmland into organic production, but the research community continues to spend only a tiny percentage of its resources on nonchemical research," he says. He hopes that researchers will look at a broad systems approach and try to understand soil biology and that more cooperation between farmers and researchers will result in new and more effective farming methods.

One of his most important concerns is what will happen to nursery stock with the loss of methyl bromide. Organic growers, like all growers, depend on certified nursery stock, which is currently grown with the help of methyl bromide to be disease and pest free. "I have some ideas on alternative methods that use a sterile medium and manipulation of temperature and day length," he says. "The problem is that my ideas are expensive."

ARS plant pathologist Carolee Bull, at the Crop Improvement and Protection Research Unit in Salinas, California, has been focusing on biologically integrated cropping systems for disease control. "We have developed an integrated research program that involves farmers and other scientists in multidisciplinary approaches to the problems that face our local farmers," says Bull. The lab is working on several projects involving organic agricultural systems that could be alternatives to methyl bromide use.

One of Bull's most significant projects is the BASIS-OASIS (Biological Agricultural Systems in Strawberry-Organic Agricultural Systems in Strawberry). "Our goal is to develop a set of biological approaches for growers to use in addition to their current management practices," Bull says. The interdisciplinary project is funded by the University of California Sustainable Agricultural Research and Education Program (SAREP) and involves the efforts of farmers, plant pathologists, weed scientists, entomologists, soil scientists, and erosion control specialists. Biological approaches, including bacterial biological control agents that were developed for conventional farming, are being tested in organic systems. Research includes the enhancement and release of beneficial species such as soil inoculants, beneficial predatory insects, insectary plants,

nonchemical weed control methods, trap cropping, and erosion control methods.

SAREP associate director and lead scientist for the methyl bromide alternatives grants program at the University of California, Jenny Broome, who is funding Bull, points out that "instead of replacing one chemical with another, farmers learn from other successful farmers and from researchers about biological farming systems that are less reliant on chemical controls." The project is still in its first year, but researchers hope it will provide lasting benefits to the strawberry industry.

Bull and her team are also trying to determine what role plant pathogens may play in the lower yields reported in organic production. They are evaluating biological control agents for their ability to increase growth and yields in nonfumigated soils. Among the tested agents are commercially available inoculants as well a mychorriza isolated from the strawberry rhizosphere. "We have found agents that increase plant growth and yield," Bull says. "The difficulty is extrapolating from a conventional production system to an organic system." These agents may be useful to the organic industry if the companies marketing the products are interested in pursing OMRI [Organic Materials Review Institute] registration."

Specifically helping organic farmers was not in ARS plant physiologist Aref Abdul-Baki's mind when he began developing a basically nonchemical production system for fresh-market tomatoes, using hairy vetch as an organic mulch. But his system has proved so successful in the mid-Atlantic region that he is now collaborating with scientists and officials in Florida and California to tailor a version of the system for winter tomatoes and other vegetables that can combat root-knot nematodes. These nematodes are one of the major problems faced by tomato producers in south Florida and southern California.

Abdul-Baki's system integrates a number of cultural choices, including growing nematode-resistant cover crops such as cowpea varieties, white clover, and sunn hemp; selecting nematode-resistant tomato cultivars such as Sanabel and Sunjay; and each planting season rotating with crops that are not hosts to nematodes, such as wheat, rye, and sorghum, followed by tomatoes. He is currently finishing the first year of testing to find the most effective cover crop for subtropic regions.

"A single change that is as effective as methyl bromide is almost impossible," says Abdul-Baki. "While no one approach is likely to lead to effective control of all nematodes, integrating several cultural practices into one alternative production system could result in an effective approach. Vegetable and cover crop cultivars can be rotated to reduce the incidence of soilborne pathogens and populations of root-knot nematodes," he says.

Technical Reports

Economic Aspects of Fumigation in Southern Forest Nurseries

William A. Carey, Auburn University Southern Forest Nursery Management Cooperative

A Technical Report in the last issue (vol. 5, no. 3) summarizes some $4 million in USDA-Forest Service research on fumigation alternatives in bareroot nurseries. Reported by region, the section on the South indicates some nurserymen there waste fumigation. Forest Service researchers never observed disease in southern trials and despite persistent weeds always considered that "seedling quality and quantity in the control (non-fumigated) plots were acceptable."

The Auburn University Southern Forest Nursery Management Cooperative has conducted fumigation studies similar to those of the Forest Service across the South since 1993. Although both research efforts report persistent weeds and little mortality from disease, the Co-op's focus on economics leads to a radically different conclusion about the value of fumigation to seedling quality and quantity. To support our position, some costs and values for our seedlings is needed.

As the Forest Service reported, about 1.2 billion forest tree seedlings, or 80% of the US total, are produced in the South each year. About 90 percent of these are produced by members of our Co-op, in just over 50 nurseries with average nursery productions of about 20 million seedlings. Through mechanization and economies of scale, most of these

seedlings sell for an average price of only $ 0.035 each. Nevertheless, with about 29,000 square foot of bed surface per production acre, that price makes each seedling/ft^2 represent $1,006 in potential sales. An average seedbed density of about 24 seedlings/ft^2 makes an acre of seedlings valuable indeed. Fumigation costs could be paid for by only 1.2 to 1.5 more seedlings/ft^2. Although Forest Service researchers considered their non-fumigated plots acceptable, they report an average increase of 2.2 seedlings/ft^2 in Methyl Bromide (MBr) plots over four years of a Florida study. Those 2.2 seedlings should be worth about $30,000 each year to the nursery above the cost of fumigation. In a recent Co-op study, the average increase at three nurseries was seven more plantable seedlings/ft^2 for the best fumigant. Fumigation associated reductions in weed control costs and the associated labor relief, along with the insurance against soil-born disease, need not be speculated on.

Forest tree seedlings are not an end-use product. The nursery-gate-price is a minimum valuation and their value for forest production can and should be considered. Historically, bareroot southern pine seedlings are classed as one of three grades based on root collar diameter (RCD). Grade 1's have RCD's greater than 4.8 mm, grade 2's are smaller down to 3.2 mm, and smaller seedlings are considered culls. On average, grade 1's survive and grow better than grade 2's. If, for example, grade 2's and 1's have average RCD's of, respectively, 4.5 mm and 6.5 mm, the grade 1's will be about one year ahead (in a 20-yr rotation) and have perhaps 5% greater initial survival. These considerations, in an analysis of published studies (in 1984), suggested the present value of grade 1's, on average, exceeded grade 2's by $ 0.10 per seedlings.

So many seedlings are now produced per nursery that grading and physically removing small and or diseased seedlings after harvest is no longer practical. However, an appreciation for the improved performance of larger seedlings is indicated by the trend to produce fewer seedlings/ft^2 and in the availability of low-seedbed-density seedlings at a higher price. For example, one corporation sells seedlings grown at 20/ft^2 at a 66% increase compared to those grown at 25/ft^2. The tacit assumption is that lower seedbed density seedlings are larger.

In Co-op studies, fumigation has increased both average seedling size and the number of seedlings. Increases in size and in numbers should be multiplied to estimate the real impact of treatment. For example, in the recent three study comparison, chloropicrin plus metham sodium (CMS) was the best fumigant (MBr was not tested). Compared to non-fumigated plots, CMS increased total seedlings (including culls) by only 3/ft^2 but increased grade 1 seedlings by 6.5/ft^2. If all those seedlings were sold, sales would increase $3,000/ac and present values, estimated as above, would increase $26,000/ac. Nursery reputations rise or fall in time with product quality so there is value to the nursery beyond the sale price. However, the present value of the seedlings is the value beyond the nursery. Should this value concern the Forest Service?

The Forest Service's research priorities remain the development of non-chemical technologies. For example, to forecast disease based on soil assay, to manage disease by organic amendments or barefallow treatments or the containerization of some bareroot production. Estimates for practical availability and cost are avoided. A cost estimate for containerization is simple; in the South it adds about $0.10 per seedling compared to bareroot production and so would add $100 million to seedling costs.

In The Biologic and Economic Assessment of Methyl Bromide (NAPIAP 1993) the largest estimated economic return per pound of MBr was $109/lb in forest tree nurseries. That equals $30,000 per nursery acre. Is that realistic? The production /ft^2 in a 1998 Georgia study was 11.5 grade 2 plus 2.5 grade 1's in control plots and 5.4 grade 2 plus 14.0 grade 1's in CMS fumigated plots. Increasing the present value of grade 1's for expected growth makes the value in control plots and in fumigated plots, respectively, $21,500 and $59,300. Evaluating fumigation in bareroot nurseries requires more than disease associated mortality.

Grape Replant Disorder—An Integrated Management Approach

S. Schneider, USDA-ARS, Postharvest Quality and Genetics Research Unit, Fresno, CA 93727, H. Ajwa and T. Trout, USDA-ARS, Water Management Research Lab, Fresno, CA 93727, and J. Sims, Dept. of Plant Pathology, University of California, Riverside, CA 92521

Pre-plant soil fumigation with methyl bromide has commonly been used to prevent or lessen "replant disorder" when replanting grapes into vineyards infested with

soilborne pests. Methyl bromide is effective against a wide range of soil pests including insects, nematodes, weeds, and pathogens. Accurate diagnosis of the specific problem in a given vineyard has not been necessary, since methyl bromide is effective against such a wide spectrum of pests. Methyl bromide can be used effectively against soil pests over a range of soil types, temperatures, and moistures resulting in greater flexibility of use and less risk of crop loss than is possible with many other soil treatments. Another strength of methyl bromide is its ability to kill old grape roots deep in the soil. If these are not killed, they serve as a reservoir of inoculum for soilborne pests.

Growers who need to replant vineyards that have existing soil pest problems will need alternatives to methyl bromide because of the scheduled ban on import and manufacture in 2005. Unless a "silver bullet" that is effective against a wide range of pests and over a range of soil conditions can be found and made available, the first challenge will be to accurately diagnose the problem(s) in a specific field. Once the problem is identified, a management strategy must be generated that is: 1) effective against the identified pest; 2) effective under the soil conditions found in that vineyard or field; 3) economically feasible; and 4) environmentally acceptable. This strategy might be a single action or, more likely, an integrated approach using multiple biological, chemical, and cultural tools and approaches.

Because of the brief time before the ban on methyl bromide is implemented, adapting the use of existing commercially available compounds as components of integrated systems is being tested as a transitional solution during the more time-consuming development of culturally and biologically based management systems. An additional level of complexity results from the spatial variability of pest populations and soil physical, chemical, and biological factors which will impact the fruit yield and quality. Some management strategies have been hindered by inconsistent performance—sometimes they work, sometimes they don't. This could be due to the spatial variability of soil factors that affect the efficacy of the management option. Understanding the biological, chemical, and physical interactions will allow growers to select options best suited to their conditions. Management strategies will have to be tailored to the specific pest problems and soil conditions in order to maximize the probability of successful replanting.

Our approach to research on the replant problem in vineyards is to identify and characterize factors contributing to the problem and then mount a two-pronged attack: first, eliminate or minimize factors that negatively impact growth and yield and, second, introduce or enhance factors that positively impact growth and yield. Novel delivery systems such as drip irrigation systems and introduction of beneficial organisms/materials into nursery materials will be evaluated.

In the fall of 1997, a field trial was initiated in a 15-year-old "Thompson Seedless" vineyard at the ARS research location in Parlier, CA. The nine treatments were:

1) a six month fallow (the untreated control);
2) a combination application of Telone II EC (35 gal/acre) in 60 mm of water through a buried drip tape plus Vapam (26 gal/acre of 42% metam sodium) applied through surface microsprinklers;
3) same as #2 except the Telone was applied in 100 mm of water;
4) a shanked application of methyl iodide (400 lbs/acre), tarped;
5) a shanked application of methyl bromide (400 lbs/acre), tarped (the treated control);
6) 18 month fallow;
7) same as #2 following an 18 month fallow;
8) same as #3 following an 18 month fallow; and
9) 18 month fallow plus a sorghum-sudangrass hybrid cover crop.

Each treatment was replicated 5 times. The telone/vapam treatments were applied in early January, 1998. The methyl bromide and methyl iodide treatments were applied in late April, 1998.

The telone/vapam combinations are novel applications which reduce worker exposure to currently available chemicals. Methyl iodide is not currently registered, but has been shown to be effective in tests on replant disorder in other crops. Fallow treatments remove the existing above ground portions of the vines and the roots that can be easily pulled out, but does not remove all of the roots, especially those deeper in the soil. An 18-month fallow results in a loss of use of the vineyard for an additional year, but also removes the actively growing vine and upper roots as biological factors in the ecosystem for that year.

In July of 1998, each plot was planted with three grape variety/rootstock combinations; own-

rooted Thompson Seedless, Merlot on Harmony rootstock, and Merlot on Teleki 5C rootstock. The rootstocks vary in levels of resistance to nematodes, which are thought to play a role in replant disorder. Data on plant growth and nematode populations will be collected for at least five years in order to determine the impact of the treatments not only on vegetative plant growth, but also on fruit yield and quality. Susceptible St. George rootstocks were interplanted between the primary vines to be used as bioassay plants to determine if the nematodes present in the soil are still infective.

Soil samples were collected from each plot at planting to a depth of 5 feet and assayed for plant parasitic nematodes. There was no significant difference between the numbers of rootknot nematode (*Meloidogyne* spp.) in the untreated control, 18-month fallow (18F), and 18-month fallow plus cover crop (18F+CC). Rootknot numbers were not significantly different between the methyl bromide (MB), methyl iodide (MI), and all four telone/vapam (T/V) combinations, and were significantly less than the untreated control. All nematodes in the MB, MI, and T/V treatments were dead and coiled, whereas the nematodes extracted from the fallow treatments were active. Numbers of dagger nematode (*Xiphinema* spp.) were slightly higher in the untreated control and 18 month fallow treatments than in the other treatments, but not significantly so. Total dagger nematode populations were relatively low across all treatments. Ring nematode (*Criconemella* spp.) was significantly higher in the 18F and 18F+CC plots than in all other treatments. Pin nematode (*Paratylenchus* spp.) numbers were higher in the untreated control, 18F, and 18F+CC treatments than all other treatments.

A qualitative rating of weed abundance was made approximately three weeks after vines were planted (7 months after the T/V treatments and 3.5 months after the MB and MI treatments). The untreated control, 18F, and 18F+CC plots contained a dense cover of weeds. The T/V plots had a few weeds. The MB and MI plots were essentially weed-free.

In February, 1999, the dormant vines were pruned back to 2 nodes above the graft union. Pruning weight per plant for Thompson Seedless vines was highest for MI plots, intermediate for the MB and T/V plots, and lowest in the untreated control, 18F, and 18F+CC plots. There were no differences in Merlot pruning weights for the Harmony and Teleki 5C rootstocks across treatments.

Soil samples were collected to a depth of 24 inches in late May 1999, approximately one year after planting, 18 months after the telone/vapam applications, and 13 months after the methyl bromide and methyl iodide applications. There were no detectable plant parasitic nematodes in any of the plots treated with methyl bromide, methyl iodide, or the telone/vapam combinations. There was no significant difference in citrus nematode populations in the untreated control, 18F, or 18F+CC treatments on each of the rootstocks and all were significantly higher than the chemical treatments for their respective rootstocks.

In the Thompson Seedless plots, rootknot nematode populations were significantly higher in the untreated control than in the 18F and the 18F+CC treatments. There was no significant difference between the ring, dagger, and pin nematode populations on Thompson Seedless in the untreated control, 18F, and 18F+CC plots.

On the Teleki 5C rootstock, rootknot nematode populations were significantly higher in the untreated control plots than in the 18F+CC, and intermediate in the 18F treatments. Ring nematode populations were significantly higher in the 18F+CC plots than in the untreated control, and intermediate in the 18F treatments. Pin nematode populations were significantly higher on Teleki 5C in the 18F+CC treatments than in the untreated control or the 18F. Dagger nematode populations on Teleki 5C were significantly higher in the 18F than in the untreated control or 18F+CC treatments.

On the Harmony rootstock, rootknot and dagger nematode populations in the untreated control and 18F+CC treatments were significantly higher than the 18F treatment. Ring and pin nematode populations on Harmony were significantly higher in the untreated control than in the 18F+CC treatments and were intermediate in the 18F treatments. Soil samples will be collected again in the fall.

Bioassay samples will be collected this summer to determine the populations of rootknot nematode in the roots. For each succeeding year of the test, soil samples will be collected in spring and fall to determine the population levels of the plant parasitic nematodes and plant growth measurements will be made. Evaluation of the soil samples for other biotic and abiotic factors will be conducted as resources allow. When the vines

begin bearing fruit, fruit yield and quality will also be evaluated. The entire experiment is being repeated in 1999.

Additional lab and greenhouse tests are being conducted to evaluate various biological, chemical, and cultural management strategies for their negative impacts on pests and positive impacts on plant growth. Agri-50, a colloidal compound, prevented hatch of rootknot nematode eggs at high concentrations and killed infective juveniles at lower concentrations. Greenhouse and field tests are being conducted to evaluate this product in a soil ecosystem. Ceres and Liqui-comp, both microbial products, appear to enhance plant growth in preliminary tests in non-fumigated field replant soils, but did not kill rootknot juveniles or eggs in the lab.

In the short term, novel applications of currently available chemicals appear to be the most likely alternatives to methyl bromide. These will serve as stepping stones during the transition to an integrated systems management approach based on an understanding of the interactions and spatial variability of biological, chemical, and physical factors in the agroecosystem. Such a system will include management strategies to reduce or eliminate pests, enhance beneficial organisms, promote good plant growth, kill old roots deep in the soil that serve as pest reservoirs, and protect the environment.

New Editor

Sharon Durham joins the ARS Information Staff as the new editor of the USDA *Methyl Bromide Alternatives* Newsletter. She can be reached at 5601 Sunnyside Ave., Beltsville, MD 20705–5129; phone (301) 504–1611, fax (301) 504–1641; e–mail sdurham@asrr.arsusda.gov